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Selection and Application Guide to Police Body Armor

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Technology Assessment Program
Standards Laboratory

Selection and Application Guide to Police Body Armor

September 1981

U.S. Department of Justice
National Institute of Justice
Office of Development, Testing, and Dissemination

National Institute of Justice

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INTRODUCTION

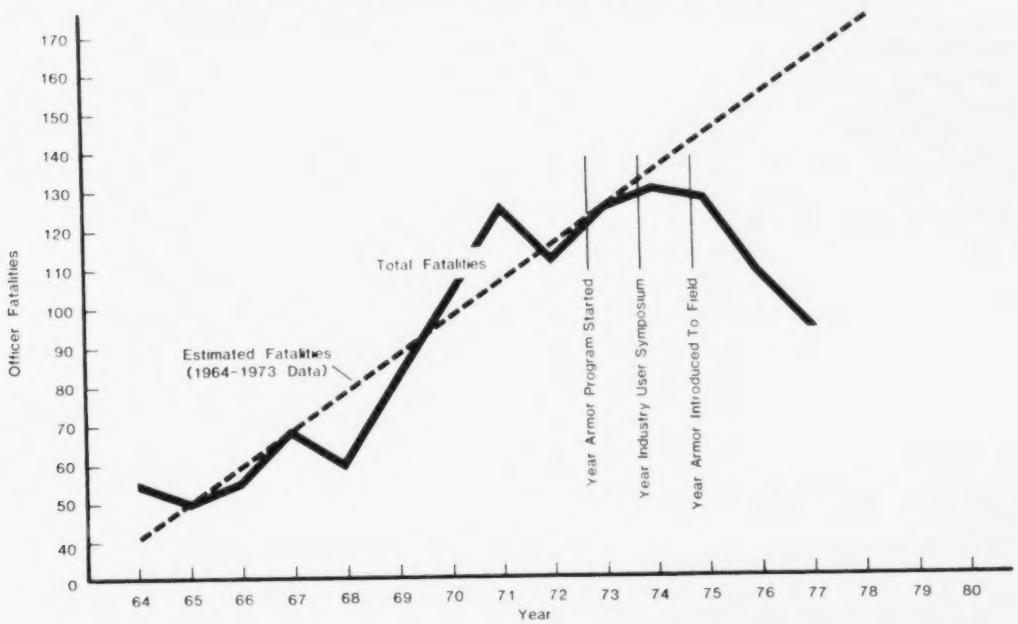
The life of a law enforcement officer is in constant danger. When an officer responds to a call for assistance and knows that an individual with a weapon is involved, there is time to take precautions to protect and defend against the threat, reducing the risk to the officer. It is not surprising, then, that officers are most often killed or injured during incidents in which the attack is totally unexpected.

The rapid increase in police injuries and deaths from assault with guns and knives during the period from 1960 to 1970 prompted the National Institute of Law Enforcement and Criminal Justice (NILECJ) [now the National Institute of Justice (NIJ)] of the Law Enforcement Assistance Administration (LEAA) to sponsor a major program to develop a lightweight body armor that an officer could wear on a full-time basis throughout an entire working shift.

The rationale for this program is obvious: If an officer always wears body armor, the vulnerability to unexpected assault is greatly reduced. While armor that could be concealed under normal clothing was available at that time, it was too heavy and uncomfortable, and most officers would not wear it even if they had it. NILECJ developed an armor that was considered suitable for full-time law enforcement use. Some 5,000 protective garments were field tested by volunteer officers in 15 law enforcement agencies throughout the country, demonstrating that it was practical for an officer to routinely wear such armor.

Even before the NILECJ field test program was initiated in 1975, the State and local governments began to purchase the new body armor for their officers, and many officers purchased their own if their department did not provide it. There is no question that the routine use of body armor has saved lives. A sharp reduction in law enforcement officer fatalities, beginning in 1975 when the armor was introduced in quantity, is readily apparent inFigure 1. Fatalities have been reduced from a high of 134 in 1973 to 94 in 1978, even though the assault rate has remained relatively constant.

FIGURE 1. RECENT TRENDS IN OFFICER FATALITIES



Recognizing that effective body armor would become a standard item of law enforcement equipment, the National Bureau of Standards' Law Enforcement Standards Laboratory (LESL), in concert with NILECJ and the U.S. Army (Biophysics Branch, Research Division, CSL, Edgewood Arsenal, Md., and Natick R&D Command, Body Armor Group, Natick, Mass.), began the development of a performance standard for lightweight body armor. The development of this standard insures that one can purchase armor that provides a known level of ballistic protection. The standard has been revised once already, and will likely be revised in the future. Those wishing to use the standard in procurement actions should contact LESL to obtain copies of the most recent standard at the time of such action. Similarly, the International Association of Chiefs of Police (IACP) will gladly provide the latest information concerning their tests of body armor, and they, too, should be contacted prior to a procurement action.

The primary purpose of this guide is to assist law enforcement agencies and individual officers in the selection of lightweight body armor that meets their needs. The sections that follow are intended to acquaint the reader with the factors that were taken into account in the development of lightweight body armor; assist the user in defining the threat levels that should be protected against; discuss the application of performance standards; describe the currently available commercial body armor; and direct the reader to the results of testing conducted by the IACP to evaluate these products in accordance with the standards that LESL has developed.

In addition to the primary purpose of this guide, it is hoped that the information presented will help the law enforcement community become more aware of the benefits of the routine use of body armor, and will encourage all officers to wear their armor full-time.

IMPORTANT: OFFICER SHOULD WEAR PROPER BODY ARMOR FULL—TIME DURING WORK SHIFT.

OFFICER PUTTING ARMOR ON AT THE BEGINNING OF HIS WORK SHIFT.

OFFICER WEARING ARMOR DURING NORMAL DAILY ROUTINE.

OFFICER PREPARED FOR ANY SITUATION BY WEARING BODY ARMOR.

BACKGROUND

Metal armor played an important role in military operations during the centuries prior to 1700 when it was used to protect the soldier from sword, battle-axe, arrow and lance. The introduction of gunpowder quickly made metallic armor obsolete. It was not until World War I that body armor was again introduced on a limited basis to protect soldiers. During World War II, a search for a non-metallic ballistic resistant material was initiated, in part because of the shortage of suitable metallic materials, and also in an effort to reduce the overall weight of the armor.

The primary purpose of military body armor is to provide protection to infantry soldiers against a variety of fragmentation type munitions. By far the highest percentage of military casualties is caused by fragments from grenades, mortars, mines, etc. In contrast, law enforcement officers are most often assaulted with handguns, at least 80 percent of which are .38 caliber or smaller.

The U.S. military has made extensive use of ballistic nylon cloth and Doron, a resin-impregnated glass fiber laminate, in the design of protective garments to minimize fragmentation injury During the original development efforts, and subsequent to World War II, the same garments were also evaluated for handgun ballistic protection characteristics. While fragmentation protection jackets do provide a degree of protection against handguns, the bulk, weight, and conspicuousness is such that they are not suitable for constant use, particularly during the normal activities of a law enforcement officer.

It was recognized that individuals exposed to the threat of assault with handguns, particularly law enforcement officers operating in undercover situations, would be willing to accept some degree of discomfort and excessive weight if they had access to concealed body armor. Similarly, when responding to a "man-with-gun" call, it made good sense to use body armor, and bullet-resistant vests became commercially available for law enforcement use. These garments were not, however, used routinely.

NILECJ recognized that the properties of a new material, Kevlar®* 29 aramid, introduced by E. I. Du Pont de Nemours & Co. and investigated by the Army's Natick Laboratories and Materials and Mechanics Research Center (AMMRC), filled the need for a lightweight ballistic-resistant material that could be used to construct lightweight body armor for police use. The efforts of NILECJ to develop such an armor were directed toward several specific objectives: comfort, inconspicuousness, light weight, protection against common handgun threats, and perhaps most important , wearability for a full duty period. These objectives were fully achieved, and the effectiveness of body armor in routine police application has been demonstrated.

In order to provide a frame of reference for the discussions which follow, it is necessary to introduce the concept of limited protection, for this concept formed the basis upon which the new body armor was developed, and is central to the selection of protective garments that are appropriate to the needs of the user. Simply stated, the concept of limited protection recognizes that it is impossible to completely protect a law enforcement officer from all possible threats with a body armor that can be worn continuously. Thus, it becomes necessary to define a reasonable threat level to protect against, with some risk of injury when the armor is worn. The limits of this risk had to be established in order to produce an acceptable garment.

The NILECJ objective, based upon the normal street threat, was to accept a 95 percent probability of survival after being hit with a .38 caliber bullet at a velocity of 800 feet per second. Further, the probability of requiring surgery if hit by such a projectile was to be 10 percent or less.

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*Du Pont registered trademark.

*The use of brand names in this guide in no way constitutes endorsement of these products by the National Bureau of Standards or any other agency of the Federal Government.

By routinely wearing body armor during all working shifts, an officer is assured of full-time protection from the most likely threat, and is expected to have available other armor such as those incorporating steel or ceramic plates, for assignments involving higher threat levels such as are encountered in armed, barricaded confrontation. Under the latter circumstances, an officer would be expected to use special purpose armor, since mobility is not a major concern, and the discomfort of the armor is tolerable in the face of such a threat for a limited time.

With this background in mind, we turn to discussions of a variety of factors that influence the selection of armor for specific applications.

BALLISTIC PROTECTION

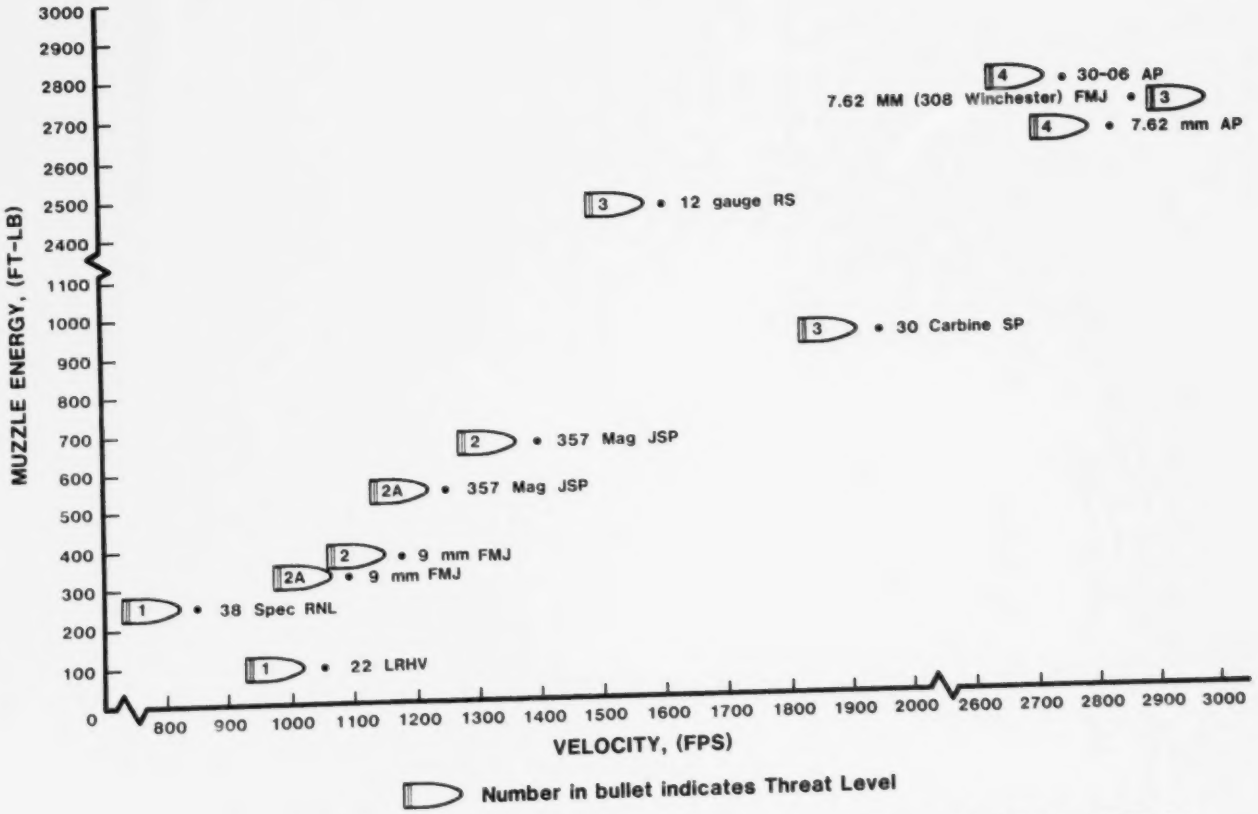
The extent of the injury that is inflicted upon an individual who is hit by a bullet depends upon the mass, shape, composition, and the velocity of the projectile upon impact with the body. Obviously, the location of the hit and its path through the body are the major determinants of whether the individual is seriously wounded or killed. Figure 2 shows a plot of the muzzle energy of common threats as a function of the projectile velocity. These data form the basis for establishing a system to classify the threat levels of various bullets.

The most common threats to police officers are from .22 and .38 caliber bullets, which are classified as threat level I. This is clearly the minimum threat level that an officer should be protected against during a normal working shift, for it includes approximately 85 percent of the street weapons that were in the 10-year period from 1964 to 1974. The remaining threat levels (IIA, II, III, and IV) extend the classification to threats as great as the 30-06 armor-piercing round. This will be discussed in more detail in a later section.

The use of metal to provide ballistic protection is easy to visualize. When a projectile strikes the surface, it can completely or partially penetrate the metal, or penetration can be completely prevented. In the latter case, depending upon the thickness of the metal, the projectile may or may not cause a deformation on the rear surface of the metal sheet. Penetration is clearly unacceptable for armor. However, limited deformation may not result in an injury to the individual wearing the armor. The extent of deformation can be controlled by simply varying the thickness of the metal sheet. The final thickness of the armor determines the weight that the individual must contend with if it is worn; consequently, all armor designers seek to keep the weight to a minimum. The figure of merit that is used to select materials for the design of an armor to provide ballistic protection against a specific threat is areal density, the weight of the armor per square foot or square meter. The greater the areal density required to protect against a specific threat, the more the armor will weigh. Metallic armor is heavy, and depending upon the material composition, can have another disadvantage; projectiles that partially penetrate some metallic armor can cause secondary fragmentation of the rear surface. The resulting fragments can be lethal.

Soft body armor, the type developed by NILECJ for police use, consists of multiple layers of flexible fabric, unlike metallic armor that is generally a single sheet of material. The ballistic protection of such armor is basically determined by the type of fabric and the number of layers that are used. The fabric that is used in soft armor consists of individual yarns that are

FIGURE 2. MUZZLE ENERGY/VELOCITY CHARACTERISTICS OF COMMON FIREARMS



The threat levels defined in the early work (~1972) fortuitously bracketed rounds in order of increasing muzzle energy. Such a simple correlation can not always be made. Consider the two rounds having muzzle velocity near 2800 FPS; they have nearly the same muzzle energy, but are so different in threat, that they require two different levels of protection. Other rounds lying near one another in this plot also demonstrate that besides muzzle energy and velocity, additional factors must be considered in defining threat level (e.g., bullet configuration and composition, and the effect of blunt trauma). For a given round, a change in powder charge will change the velocity and muzzle energy, and may change the threat level, e.g., 9mm and 357mag.

woven by conventional textile manufacturing processes. Some of the mechanical properties that determine the resistance of the fabric to ballistic penetration are the tensile strength of the individual strands of yarn (the force required to break the yarn when it is stretched) and the dynamic fiber elasticity. In addition to the inherent strength of the yarn, the manner in which it is woven is also critical; the yarn should be closely woven.

The textile industry measures the fineness of yarn on the basis of the weight per unit length, referred to as denier*. The larger the denier of the yarn, the greater its diameter. In some cases, the fabric is woven from two or more strands of yarn that are twisted together; in this instance the classification is, for example, 400/2, meaning that two strands of 400 denier yarn are twisted together to form a two-ply yarn. The number of warp and filling yarns per square inch of fabric will depend upon the size of the yarns, how closely the yarns are woven, and the specific weave of the fabric. The plain weave fabrics of Kevlar® used during the NILECJ body armor development program were woven from 400/2 and 1000 denier with a construction of 36 x 36 (warp ends per inch x filling pics per inch) and 31 x 31, respectively. Because of cost and availability 1000 denier Kevlar® is used in most presently available body armor.

Recently, 1500 denier Kevlar® 29 has been used to manufacture very effective casualty-reducing military fragmentation armor. Cloth woven from 1500 denier Kevlar® 29, however, is not as ballistically efficient as cloth woven from 1000 or 400/2 denier Kevlar® 29. Consequently, for a given threat level, a bullet resistant vest manufactured of 1500 denier Kevlar® 29 must incorporate more plies of fabric than one manufactured from 1000 or 400/2 denier Kevlar® 29. It should be noted that quality control is essential during the production of fabric of Kevlar®, or any other ballistic-resistant fabric, to insure that garments manufactured from the fabric will consistently provide the level of protection that is expected. Detailed specifications for cloth of Kevlar® and various body armor items are listed in the bibliography. These are available from the U.S. Army Natick R&D Command.

Table 1 presents a summary of the characteristics of Kevlar® 29. It is readily apparent that this material is ideally suited for use in the construction of lightweight body armor. There are, however, a number of other materials that can be used separately, or in combination with Kevlar® to manufacture body armor. Table 2 summarizes a number of materials that were considered during the NILECJ program to develop body armor.

TABLE 1. PHYSICAL PROPERTIES OF KEVLAR® 29 YARN

Parameter	Property	Comment
Density	1.44 g/cm^3	Forty percent less than glass or boron
Tensile strength	400,000 psi	Substantially above conventional organic fibers, greater than steel
Modulus	9×10^6 psi	Twice that of glass fibers
Chemical resistance	Good	Resistant to solvents, fuels and lubricants; cannot be dyed
Temperature resistance and flammability	Excellent	No degradation in short-term exposures to 500 °F, self-extinguishing
Textile processibility	Excellent	Readily woven on conventional looms

*Denier is defined as the weight in grams of a 900-meter length of yarn.

TABLE 2. **BALLISTIC RESISTANT FABRIC CHARACTERISTICS**

Material	Manufacturer	Selection criteria				
		Weight to strength penetration characteristics	Flexibility (nonrigid)	Cost	Blunt trauma	Tailoring
Nylon	Du Pont	P	G	G	G	G
Rayon	Du Pont	P	G	G	P	G
Dacron® polyester	Du Pont	P	G	G	P	G
Kevlar® 29 aramid	Du Pont	G	G	G	G	G
Thornel® graphite yarn	Union Carbide	P	P	P	P	P
Panex® graphite yarn	Union Carbide Stackpole Inc.	P	P	P	P	P
Marlex® X-P	Phillips 66	G	P	P	G	P
X-55 fiber	Monsanto	P	F	F	P	F
Nylon felt	Du Pont	P	P	P	P	P

G = Good F = Fair P = Poor

In addition to desirable characteristics, fabrics of Kevlar® and other organic fabrics have one attribute that is not desirable—the ballistic protection that they afford is reduced when they are wet. Once the Kevlar® has dried out, it regains full ballistic protection capability. Consequently, no fabric of Kevlar® should be used in body armor that has not been properly treated to make it water repellent, or contained within a sealed waterproof cover. Treatment by reputable commercial fabric finishers with an approved water repellent such as modified Zepel* D fabric fluoridizer or Scotchgard** fabric fluoridizer minimizes the problems even when the Kevlar® is totally saturated with water.

The discussions of yarn and fabric characteristics and the data presented in this section are provided only to acquaint the reader with the variety of factors that contribute to the ballistic protection afforded by soft body armor. The manufacturers of such armor frequently describe their product in terms of so many layers of such a fabric. While information concerning the construction and materials of a given body armor may assist in comparing the products of different manufacturers, the purchaser must not base the selection solely upon design criteria. The primary factor that an individual should be concerned with when purchasing body armor is the threat that it protects against, and this can only be determined by valid testing.

***DuPont registered trademark.**

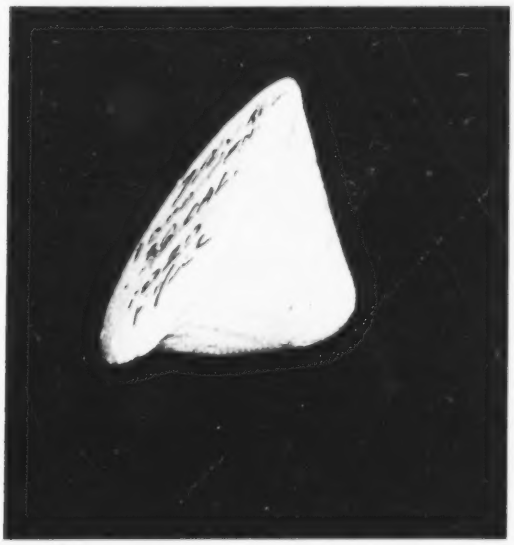
****3M Company registered trademark.**

BLUNT TRAUMA

The previous section of this guide discussed the ballistic protection characteristics of armor in terms of preventing penetration, only briefly mentioning the deformation of the armor upon the impact of a projectile. Resistance to deformation is so vital a part of ballistic protection that it warrants discussion as a separate topic.

Deformation of body armor, nearly impossible to prevent in soft body armor when attempting to use the minimum areal density, can result in blunt trauma. Blunt trauma, as opposed to penetrating trauma, is the injury that is sustained by an individual at the point of impact, behind the protective garment, when the ballistic threat is defeated. It is due to material deformation that locally deforms the body wall as a conical depression, and momentum transfer that occurs when a high-energy projectile impacts armor. Blunt trauma can cause severe contusion (bruise) and/or internal damage, and even death.

The individual officer and the police administrator must be aware of the possibility of blunt trauma, so that any time that an officer has been shot while wearing armor, medical examination of the victim should be made as soon as possible. Even though the officer shows no after effects other than soreness or a bruise, the possibility of serious internal injury exists. Prompt medical attention will minimize the risk of serious complications.



PLASTER CAST OF DEFORMATION IN CLAY BACKING FOR PROTECTIVE GARMENT FOLLOWING FIRING OF TEST ROUND.

The medical staff of the Maryland Institute for Emergency Medicine, Baltimore, Maryland, recommends the following examinations of officers shot while wearing body armor:

- All victims of assault should be hospitalized for observation in spite of an apparent state of good health and a minimal skin lesion.
- Strikes to the chest should be monitored with serial chest x-rays.
- Strikes to the precordial region require cardial monitoring and serial ECG's and enzyme determinations.
- Strikes to the abdomen require frequent examination for signs of peritoneal irritation. Impacts over the liver should be viewed with great suspicion of underlying hepatic injury.

The personnel at Edgewood Arsenal conducted extensive tests to establish a suitable criterion for the amount that armor can deform, with a high probability that serious blunt trauma would not occur. The instantaneous deformation of soft body armor upon impact was carefully determined by tests that monitored the back face signature (deformation) when the armor was impacted with a variety of projectiles. The temporary cavity that is created in a body occurs in an extremely short period of time, typically less than 2 ms. The test program was extended by the medical staff to include detailed experiments with animals, shot with protective garments in place, and later sacrificed and autopsies performed to enable medical assessment of blunt trauma.

The data from the back face signature tests and the animal tests were correlated, and a limit of deformation of 44 mm (1.73 in) was selected as the performance requirement, as specified in the NILECJ Standard that was developed by LESL. This limit is considered to be a very safe limit for humans. Additionally, actual experience supports this test evidence that blunt trauma to this limit will not kill or seriously injure the wearer.

During the field tests of the body armor that NILECJ distributed to volunteer officers, conducted in 1975, there were five instances in which the participants in the program were shot while wearing their armor. In each case, NILECJ dispatched medical examiners to interview and examine the officer involved. There were no instances in which the officers required surgery as a consequence of blunt trauma. Complete statistics concerning assaults on officers while wearing body armor are not available; however, as of the end of 1979 at least 200 lives have been saved by body armor.

BODY ARMOR PERFORMANCE STANDARD

An individual or department wishing to purchase equipment of any kind has three basic options: 1) buy on the basis of a specific manufacturer and specific model, 2) base the purchase order on a design specification, or 3) base the purchase order on a standard for the type of equipment that is being procured. The first option gives the purchaser little protection if the equipment proves to be unsatisfactory in the intended application. The second option requires a staff that knows about the necessary armor characteristics and is capable of structuring a specification or the use of an existing, well-proven one that includes all pertinent requirements and quality assurance provisions. Also needed is access to personnel that are qualified to be responsible for material testing and finished item inspection. When a detailed specification is used, the purchaser maintains complete control over every aspect of the garment, including materials, design, and construction. However, since most individuals or police departments do not have these resources, it is more practical for them to exercise the third option, the use of a well-structured standard. A properly structured standard includes detailed requirements for the most essential attributes of the equipment and provides reasonable quality assurance for the less essential ones.

The standard that LESL developed for NILECJ is issued as a voluntary national standard. This document, NILECJ-STD-0101.0l, "The Ballistic Resistance of Police Body Armor," has been reviewed by the National Advisory Committee for Law Enforcement Equipment and Technology and adopted by them as an IACP Standard. This document is a performance standard, and includes both specific requirements for body armor attributes, and methods of test to ascertain whether a given armor conforms to the standard. This standard primarily addresses the ballistic requirements.

All standards that are developed by LESL are performance standards, as opposed to design standards that specify the manner in which an item of equipment must be manufactured. Performance standards are preferred, for they go directly to the heart of the matter by clearly presenting requirements that specify a minimum satisfactory level of performance for each attribute that is critical to the manner in which the equipment accomplishes its intended use. Performance standards by nature do not inhibit the ingenuity of the manufacturers, and in fact, encourage design innovation and the use of advanced technology.

NILECJ-STD-0101.01 was issued in December 1978 as a revision to NILECJ-STD-0101.00, dated March 1972. The previous edition of the standard did not include requirements for blunt trauma, which were as yet undefined, and provided only three threat level classifications. The experience gained through application of the earlier standard demonstrated the desirability of expanding the threat level classifications. As protection against blunt trauma, an allowable limit of deformation [44 mm (1.73 in)] was established from laboratory measurements and incorporated as a performance requirement in the revised standard.

The current edition of the standard, revision .01, provides requirements for five threat levels as presented below:

- Type I (22 LR—38 Special)

  Armor that provides protection against the 22 LR (handgun) and 38 Special projectiles.

- Type II-A (Lower Velocity 357 Magnum—9 mm)

  Armor that provides protection against the lower velocity 357 Magnum and 9 mm projectiles. It also provides protection against rounds included in the Type I threat classification.

- Type II (Higher Velocity 357 Magnum—9 mm)

  Armor that provides protection against higher velocity 357 Magnum and 9 mm projectiles. It also provides protection against those rounds included in the Type I and II-A threat classifications.

- Type III (High-Powered Rifle)
  Armor that provides protection against the 7.62 mm (308 Winchester). It also provides protection against those rounds included in the Type I, II-A, and II threat classifications.

- Type IV (Armor Piercing Rifle)

  Armor that provides protection against 30-06 AP projectiles. It also provides at least single hit protection against those rounds included in the Type I, II-A, II, and III threat classifications.

Table 3, reproduced from the standard, summarizes the protection afforded by police body armor with respect to the threat level classifications and specific ammunition. Table 4, also reproduced from the standard, summarizes the specific tests and the performance requirements for each threat level. It should be emphasized again that velocity is critical to ballistic protection, and that armor that meets the requirements of this standard for a given test round, as specified in table 4, may not provide protection against that same round at a higher velocity, or with significantly different bullet composition (e.g., armor piercing) or shape.

Figure 3 shows the test setup for the ballistic testing of police body armor. The chronograph is used to measure the velocity of the bullet to ensure that each test round is within the range specified in the standard. The backing material behind the armor that is being tested is a soft clay material. This provides a standard backing that allows the laboratory personnel to measure the deformation of the armor following impact with a test round. The depth of deformation in the clay is measured for the first two projectiles only. Additional rounds are fired at the armor for a total of five hits. If it passes the deformation requirement and does not allow penetration for five rounds, a second set of armor is tested while wet. The armor is repositioned after each test round to expose a new area of the armor to the test bullet. Each part of armor designed to resist penetration by 30-06 ammunition is tested for only one hit, since these armors, in general, may not afford ballistic protection after being impacted once.

TABLE 3. PROTECTION AFFORDED BY POLICE BODY ARMOR

Threat	Ballistic protection afforded				
	Type I armor	Type II-A armor	Type II armor	Type III armor	Type IV armor
22 LRHV (H)	Yes	Yes	Yes	Yes	Yes
25 Automatic	Yes	Yes	Yes	Yes	Yes
32 Automatic	Yes	Yes	Yes	Yes	Yes
38 Special Lead	Yes	Yes	Yes	Yes	Yes
12 Gauge #4 Lead Shot	No	Yes	Yes	Yes	Yes
357 Magnum JSP	No	Yes (1)	Yes (2)	Yes	Yes
9 mm Luger FMJ	No	Yes (3)	Yes (4)	Yes	Yes
38 Special HV	No	Yes	Yes	Yes	Yes
22 LRHV (R)	No	Yes	Yes	Yes	Yes
45 Automatic	No	Yes	Yes	Yes	Yes
12 Gauge 00 BK	No	Yes	Yes	Yes	Yes
7.62 mm FMJ	No	No	No	Yes	Yes
44 Magnum Lead	No	No	No	Yes	Yes
44 Magnum JSP	No	No	No	Yes	Yes
41 Magnum	No	No	No	Yes	Yes
30-06 PSP	No	No	No	Yes	Yes
30 Carbine	No	No	No	Yes	Yes
12 Gauge RS	No	No	No	Yes	Yes
30-06 AP	No	No	No	No	Yes

Abbreviations:

AP—Armor Piercing
BK—Buckshot
FMJ—Full Metal Jacket
(H)—Handgun
HV—High Velocity
JSP—Jacketed Soft Point
LRHV—Long Rifle High Velocity
PSP—Pointed Soft Velocity
(R)—Rifle
RS—Rifle Slug

(1) Rounds up to 10.2 g (158 gr) with velocities up to 381±15 m (1250±50 ft) per second.

(2) Rounds up to 10.2 g (158 gr) with velocities up to 425±15 m (1395±50 ft) per second.

(3) Rounds up to 8.0 g (124 gr) with velocities up to 332±15 m (1090±50 ft) per second.

(4) Rounds up to 8.0 g (124 gr) with velocities up to 358±15 m (1175±50 ft) per second.

There has been a tendency on the part of some departments to test the ballistic resistance of armor using a variety of backing materials such as steel plate, or a thick stack of newspaper. This is a serious mistake, for such testing provides no valid information concerning blunt trauma or penetration protection. The clay backing material specified in NILECJ-STD-0101.01 was selected for use in the test methods only after extensive testing in the laboratory substantiated the fact that it was the most practical simulant available for the human torso. The clay must also be properly conditioned as described in the standard, if the resulting tests of deformation and penetration are to have validity.

The standard requires that armor be tested against the specified test rounds, both dry and wet. Wet tests are important, for it is known that the ballistic protection of untreated Kevlar® is reduced when wet, and body armor will undoubtedly be exposed to inclement weather, in addition to absorbing body perspiration. The tests are conducted to determine the ballistic protection of the torso front of all

armor,and if so designed, the back, groin, and coccyx (end of spine) protection are tested as appropriate.

Requirements and methods of test to evaluate the performance of body armor at environmental extremes that one might expect to degrade the ballistic properties, such as temperature extremes and ultraviolet radiation, are notably missing from NILECJ-STD-0101.01. This is intentional. Laboratory tests of materials such as Kevlar®, nylon, and rigid armor materials demonstrated that exposure to these environments did not significantly affect ballistic performance, and to include such tests would needlessly increase the evaluation costs. Kevlar® is inherently flame resistant; it will not support the spread of flame when the source is removed. Kevlar® does not melt, but chars at temperatures greater than 800 °F; no degradation has been found for short term exposures up to temperatures of 500 °F.

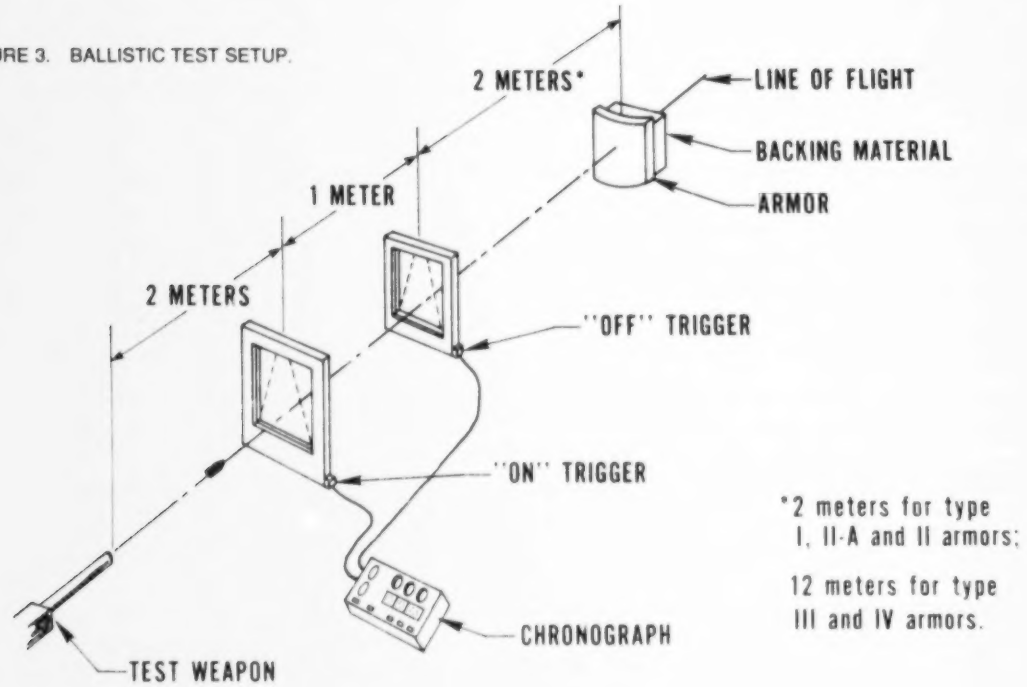
TABLE 4. TEST SUMMARY

	Test variables				Performance requirements		
Armor type	Test ammunition	Nominal bullet mass	Suggested barrel length	Required bullet velocity	Required fair hits per armor part	Permitted penetration	Maximum depth of deformation
I	22 LRHV Lead	2.6 g 40 gr	15 to 16.5 cm 6 to 6.5 in	320 ± 12 m/s 1050 ± 40 ft/s	5*	0	44 mm 1.73 in
	38 Special RN Lead	10.2 g 158 gr	15 to 16.5 cm 6 to 6.5 in	259 ± 15 m/s 850 ± 50 ft/s	5*	0	44 mm 1.73 in
II-A	357 Magnum JSP	10.2 g 158 gr	10 to 12 cm 4 to 4.75 in	381 ± 15 m/s 1250 ± 50 ft/s	5*	0	44 mm 1.73 in
	9 mm FMJ	8.0 g 124 gr	10 to 12 cm 4 to 4.75 in	332 ± 15 m/s 1090 ± 50 ft/s	5*	0	44 mm 1.73 in
II	357 Magnum JSP	10.2 g 158 gr	15 to 16.5 cm 6 to 6.5 in	425 ± 15 m/s 1395 ± 50 ft/s	5*	0	44 mm 1.73 in
	9 mm FMJ	8.0 g 124 gr	10 to 12 cm 4 to 4.75 in	358 ± 15 m/s 1175 ± 50 ft/s	5*	0	44 mm 1.73 in
III	7.62 mm (308 Winchester) FMJ	9.7 g 150 gr	56 cm 22 in	873 ± 46 m/s 2863 ± 151 ft/s	5*	0	44 mm 1.73
IV	30-06 AP	10.8 g 166 gr	56 cm 22 in	838 ± 15 m/s 2750 ± 50 ft/s	1	0	44 mm 1.73 in

*Armor parts covering the torso front and torso back, with or without side coverage, shall each be impacted with the indicated number of fair hits. Armor parts covering the groin and coccyx shall each be impacted with three fair hits. The deformations due to the first two fair hits shall be measured to determine compliance.

Abbreviations: AP—Armor Piercing LRHV—Long Rifle High Velocity
FMJ—Full Metal Jacketed RN—Round Nose
JSP—Jacketed Soft Point

FIGURE 3. BALLISTIC TEST SETUP.



In order to use the standard as the basis for a procurement, all that is required is to determine what threat level protection is desired, and the style of armor that is appropriate. For example, a suggested wording for a typical purchase order could be:

"The body armor shall meet all requirements of NILECJ-STD-0101.01 (or current edition* if a new revision is available), 'Ballistic Resistance of Police Body Armor, dated December 1978. It shall be of Type II (Higher Velocity 357 Magnum-9 mm), as defined in that standard, and shall afford protection to the torso front, torso back, and sides."

Other characteristics of body armor not addressed by the standard, such as size, weight, launderability, and type of fasteners should be evaluated in terms of what is available and what is needed by the users of the body armor. Those additional characteristics of concern to the user as well as sampling plans should also be specified in the purchase order.

Note: The standard also provides a basis for procuring body armor to meet unique protection requirements that an individual user may require that are not included within the standard threat level classification. In this instance, a purchaser having a special requirement for ballistic protec-

*The importance of contacting LESL cannot be overemphasized to be sure that the purchase order is based upon the latest edition of the standard. There is no question that body armor technology will continue to advance rapidly in the future, and in all likelihood it will become necessary to develop future revisions to keep pace with this technology and the needs of the police. Write to: Chief, Law Enforcement Standards Laboratory, National Bureau of Standards, Washington, D.C. 20234. Telephone (301) 921-3161.

tion should simply specify the exact test rounds to be used (i.e., caliber, bullet shape, bullet mass, configuration, and velocity) and state that NILECJ-STD-0101.01 shall govern in all other respects.

The standard also includes specific labeling requirements for each item of armor that is purchased (manufacturer identification; ballistic protection classified in accordance with the standard; size, lot number, month and year of manufacture; striking face, if any; cleaning instructions for the ballistic material and for the armor carrier, if any). While many manufacturers' labeling does not presently conform to this requirement, the purchaser should insist upon full compliance with the labeling requirements. The information required by the standard is essential to the user to insure that the officer knows the level of protection provided by the armor, and that it is properly maintained. In addition, the specific manufacturing data is very important. If a given set of armor is found to be defective, the department should inspect all armor from that production lot, for it is possible that the entire lot is defective.

SELECTING BODY ARMOR

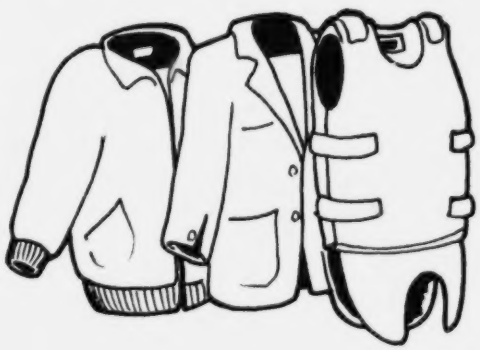
The first step in the selection of body armor that is appropriate to the needs of the user is to determine the threat level that is required. The NILECJ Standard used the statistics for all confiscated weapons, nationwide, as the basis for establishing the the Type I threat level, which is the minimum protection that any officer should have throughout the working shift.

The weapons commonly found on the street do, however, vary significantly with geographical location. It is, therefore, essential that one consider the information concerning weapons that are confiscated in both the local jurisdiction and nearby surrounding areas, as well as statistics concerning gun sales of sporting good stores. Such data will provide an assessment of the current threat of the street weapon; however, NILECJ, LESL, and IACP urge the selection of a threat level that includes the handguns that are used by the officers themselves. A review of the reports on officers killed during the period from 1970 to 1978 shows that they were assaulted with their own service weapons in approximately 20 percent of the incidents. For this reason the current edition of the standard established a separate classification, Type II-A, the threat represented by the weapons commonly used by many police departments.

The analysis of potential weapon threats that will be encountered by the police force can be expected to identify the need for armor to protect against several threat levels, depending upon the nature of the specific assignments. Obviously, any police department will require some specialized armor for such functions as SWAT team protection, but these armors will only be issued and used on an as needed basis. As noted earlier, the armor designed to provide protection against high level threats will be heavy and bulky, and will not be suitable for full-time use.

When selecting armor for full-time routine use by an officer, it is a simple fact of life that comfort becomes a major factor. Armor that is set aside or relegated to the trunk of a cruiser is of no benefit when needed most. The NILECJ development effort recognized this as a real world problem, and placed major emphasis upon comfort in the design of lightweight body armor for police use. Two fundamental factors were considered; fit—from the standpoint of mobility and the weight distribution of the armor, and heat discomfort. Both of these armor characteristics were evaluated by the U.S. Army Natick R&D Command with instrumented anatomical models of the human body. The stresses measured relative to weight distribution resulted in an improved design for the garments. Also, the dissipation of body heat through body armor was measured. These tests demonstrated that during normal activities, an individual wearing body armor should not suffer unduly from reduced dissipation of body heat; for example, the long-sleeved police uniform has about the same heat dissipation as the utility army fatigues. Adding the original NILECJ vest of Kevlar® 29 to the police uniform prevented about the same amount of heat loss as adding a helmet liner to the fatigue outfit.

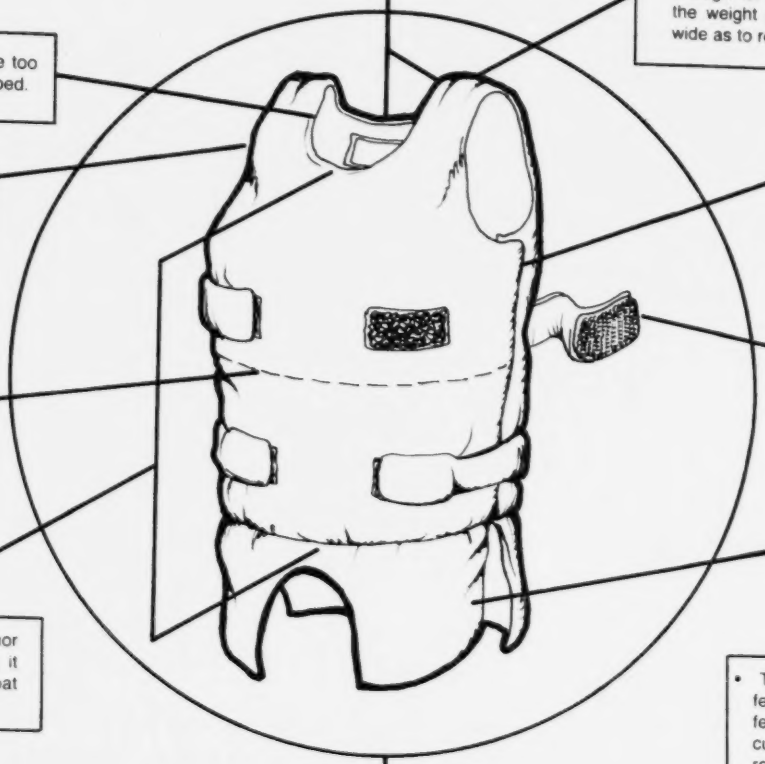
THE SELECTION OF ARMOR IS



IMPORTANT

Comfort, either with respect to fit or heat dissipation, is at best subjective and a matter of individual sensation. However, there is adequate data to suggest that body armor is suitable for full-time use and that an officer should be willing to accept minor discomfort in exchange for the protection that is afforded. If there is any serious question concerning comfort, it would be well to have members of the department wear samples of armor on a trial basis before making a major purchase.

Laboratory tests and comments from officers that wear body armor during their daily shifts have identified a number of factors that bear upon the comfort of body armor when used for extended periods of time:



- The shoulder, neck, and armholes should be feathered to minimize bulk and maximize comfort at these areas, but still not reduce the ballistic protection.
- The shoulder straps should be wide enough for comfort and to distribute the weight of the armor, but not so wide as to restrict movement.
- The neck opening should not be too high, and should be properly shaped.
- The armholes of the armor should not be too small.
- Seam construction of the armor should allow maximum flexibility and yet maintain ballistic protection.
- The armor should not be too wide or the front will overlap with the back and add needless bulk.
- The armor should permit size adjustment while retaining ballistic integrity for the sides of the torso.
- The carrier for the armor material should have a tail that can be tucked into the pants to prevent the armor from riding up.
- The length of the front of the armor should not be too long; otherwise, it will be pushed up into the throat when the officer sits or bends.
- The concealed undergarments for female officers should conform to the female anatomy; to accomplish this, curved seams in the bust area are required. The seam construction for such garments is critical. It is very important that the joined pieces overlap each other a minimum of 1 in. Particular attention should be paid to the length of the garment, which is a frequent problem. The adjustment straps for the female undergarment may be fastened to the back to improve the overall appearance of the uniform.
- The armor should be as light as possible, while still providing protection against the threat that is most prevalent in the geographical area of use.

The protective undergarment is the most widely used police body armor. Such garments are worn under the normal uniform shirt. Properly designed, these garments are relatively comfortable, lightweight (2 to 4 1/2 lb), and do not unduly restrict movement. Such armor is available in a variety of designs. It is possible to purchase armor that is constructed to cover only the front torso, with a separate section that can be added to such armor to protect the rear torso and the sides. An officer that spends nearly the entire duty shift in a vehicle may be tempted to wear only chest protection, but this is not an advisable practice.

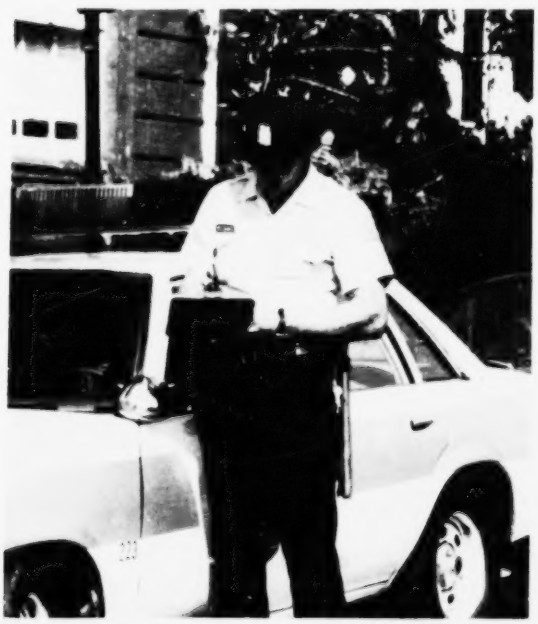
ARMOR BEING PUT IN POUCH.

Figure 4 shows a typical undergarment body armor. In this case, it is designed to provide full front, side, and rear protection and is put on over the head. The actual armor is contained in pouches in a polyester/cotton carrier. When purchasing undergarments of this type, two carriers should be ordered to permit one to be laundered while the other is worn. Metal fasteners should be avoided, for they can become secondary missiles. Hook and pile tape fasteners from Velcro Corp., which appear to be ideal, should be at least 1 1/2 in wide and should provide approximately plus or minus 2 in of adjustment. In addition, the fasteners should be anchored to a good quality elastic, about 3 in long, to facilitate proper adjustment and to compensate for body movement. While some manufacturers will custom fit each set of armor to the individual officer, most armor is purchased in stock sizes that will reasonably accommodate the majority of police officers. It is recommended that one garment or more in each size be obtained from the supplier for fitting purposes to determine size range. The protective undergarments currently available provide protection against threat levels I, IIA, and II as specified in NILECJ-STD-0101.01.

The protective undergarments of the type described above are also available with special pouches that allow additional ballistic protection of the front and, in some cases the rear, by inserting armor panels. These panels may be metal, ceramic, or rigid plastic. Depending upon the material that is used, such armor provides the protection of the threat level III or IV of NILECJ-STD-0101.01. It should be recognized that the extended protection applies to only the portion of the torso behind the insert.

The soft body armor materials enable the design of a variety of other armor configurations, which are not typically used by police officers. These include the ballistic protective outer vest shown in figure 5. In addition, raincoats, reefer jackets, and winter coats, all with ballistic liners are available as shown in figures 6, 7, and 8. Finally, one can even purchase shirts and conventional sport coats with ballistic protection, one of which provides a ballistic flap that can be positioned to protect the otherwise exposed area between the lapels of the sport coat (see fig 9). All of these styles of body armor can provide protection against the Types I, IIA, and II threat levels of NILECJ-STD-0101.01.

Body armor to provide protection against the higher threat levels (III and IV), as specified in NILECJ-STD-0101.01, will be of either semi-rigid or rigid construction. Semi-rigid armor can consist of a somewhat flexible material with im-



WHEN BODY ARMOR IS FIRST RECEIVED, WEAR IT ON DUTY FOR 30 DAYS BEFORE DECIDING WHETHER OR NOT YOU LIKE IT. IT TAKES TIME TO GET USED TO IT.

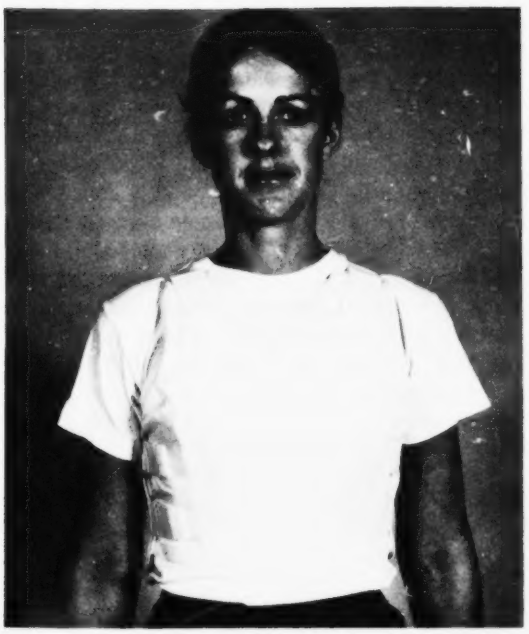


FIGURE 4 (b) WOMAN'S UNDERGARMENT NLPACA

FIGURE 5. BALLISTIC PROTECTIVE OUTER VEST.

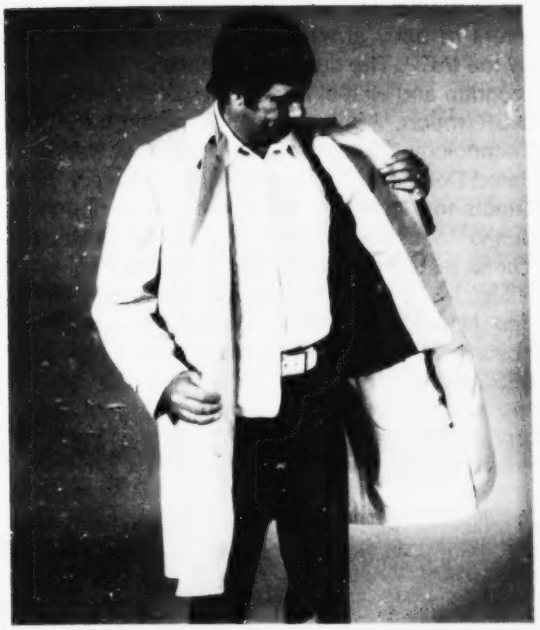


FIGURE 6. RAINCOAT WITH BALLISTIC OR THERMAL LINER.

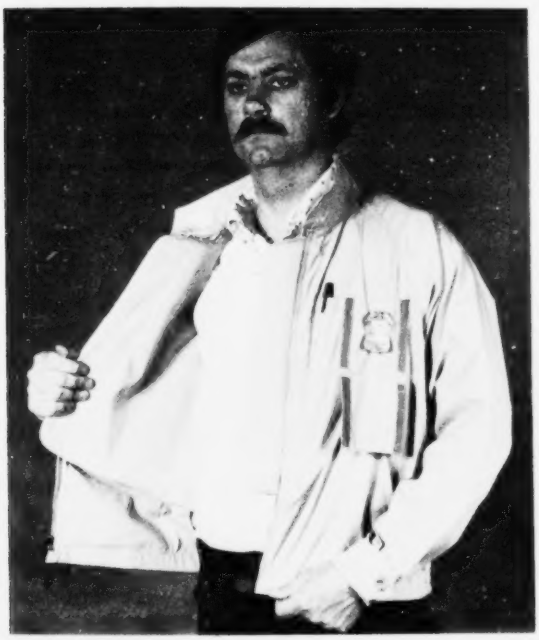


FIGURE 7. POLICE REEFER COAT WITH BALLISTIC LINER.

pregnated ballistic fabrics or a garment composed of small articulated plates of ballistic material such as steel or plastic reinforced with glass or Kevlar® (GRP and KRP), borrowing from the naturally occurring armor design of the armadillo. Semi-rigid vests, difficult to conceal, allow the use of dense materials (high areal density) while retaining limited movement.

Rigid body armor is composed of molded ballistic material (GRP, KRP, metals, or ceramics) designed to cover certain portions of the body. Rigid body armor is the most restrictive of body movement and is also difficult to conceal. In general, semi-rigid and rigid body armors would only be used for short periods of time under circumstances of expected confrontation with high-level threats.

If such armor is included in the department's inventory, the officer who uses it should be aware that ceramic armor, most frequently constructed of boron carbide, aluminum oxide, and silicon carbide, is extremely brittle. These armor materials are normally bonded to GRP or KRP for body armor purposes. The ceramic should be inspected for any evidence of surface cracks before use; for if cracks exist the ballistic performance will be degraded. Such armor should not be dropped on hard surfaces, and when used, the ceramic must be used as the striking (exterior) surface.

GRP and KRP, which will delaminate when impacted by a bullet, and ceramic armor constructed as a mosaic with a GRP or KRP backing have limited multiple hit capability depending upon the point of impact of each round. Laboratory tests of blunt trauma with respect to use of GRP, KRP and ceramic/GRP or KRP armor have been made. Both materials should pose little hazard from blunt trauma.

This guide has placed primary emphasis upon the ballistic protection characteristics of body armor, recognizing that firearms are not the only threat to a law enforcement officer, since many officers are injured as a result of assault with knives or razors. The threat posed by a given

firearm/ammunition combination is well defined. The variety of knife configurations available on the street, coupled with the manner in which an individual might use the knife, and individual strength characteristics have to date prevented the development of a valid classification system for knife threats and a corresponding performance requirement for such protection.

FIGURE 8. POLICE WINTER JACKET WITH BALLISTIC LINER.

Limited experiments have been conducted to evaluate the protection of armor against a 10-in butcher knife, a bayonet, and a 4-in switchblade knife. The knife is easily defeated by any of the hard armors. While the knife resisting characteristics of soft body armors are not completely defined, some general statements can be made. Body armors made of nylon and/or Kevlar® will defeat a common butcher knife threat and will protect against razor slashes. Soft body armors provide little protection against a straight thrust with an ice pick, and protection against a narrow blade instrument such as a switchblade is limited and very dependent on the angle of the thrust.

As of the fall of 1979, there were 17 manufacturers of body armor, all of which were tested by the IACP. The complete details of the testing program and all test results are presented in the IACP report, "Police Body Armor, Equipment Technology Center, Consumer Product Report," dated December 1978, and supplementary data sheets to this report that present data obtained during additional tests of certain products. These tests were conducted in accordance with NILECJ-STD-0101.01, dated December 1978. The National Bureau of Standards' Office of Testing Laboratory Evaluation Technology and LESL assisted the IACP in the selection of the two laboratories that were awarded contracts to test body armor, and in monitoring the test program.

FIGURE 9. BALLISTIC SPORT COAT WITH BALLISTIC FLAP IN PLACE.

Copies of the IACP report and current test results may be obtained directly from the Equipment Technology Center, International Association of Chiefs of Police, 11 Firstfield Road, Gaithersburg, Md. 20760. Telephone requests

can be made through the IACP toll-free number (800) 638-4080.

Those wishing to apply the results of the IACP testing should obtain the complete report, for there is additional data included within the document that will assist the user in identifying armors most suitable for use in a variety of applications. The user will then be able to solicit competitive bids from several manufacturers that offer armor consistent with the requirements unique to the user's department.

MAINTAINING BODY ARMOR

When an individual purchases body armor for personal use, or is issued body armor by a law enforcement agency, the first suggestion is obvious—use it all of the time. As previously noted, body armor can save an individual's life because most assaults occur without warning under circumstances that would not be expected to result in an attack on the officer.

When an individual wears body armor routinely, the knowledge of protection against the common threats that will be encountered should be comforting. However, keep in mind that the armor was selected on the basis of limited threat protection. There is no such thing as "bullet-proof" armor. There exist weapon and ammunition combinations that will defeat any armor that is designed. Consequently, do not tempt fate. If it becomes necessary to respond to a call and it is known that you may be exposed to a weapon threat in excess of the known protection provided by your normal armor, take the time to obtain additional protection, including the use of ballistic helmets (the subject of a separate LESL guide).

Based upon experience to date, the actual service life of protective armor that is properly maintained should be almost unlimited. For practical purposes, however, to provide a margin for safety, soft body armor is generally considered to provide a 5-year service life.

The proper care of body armor that is constructed of Kevlar® includes taking precautions when cleaning the garment. Every garment should have a label with instructions on how to clean the Kevlar® components. Follow these instructions. Generally, Kevlar® components can be machine or hand washed in hot water with any mild home laundry detergent. DO NOT USE BLEACH OR STARCH AND DO NOT WASH AT A COMMERCIAL LAUNDRY. Rinse thoroughly to remove all traces of soap and machine dry at the highest setting of the dryer. Perchlorethylene is the only dry cleaning solvent so far found that will not significantly degrade the ballistic protection afforded by Kevlar®. However, to eliminate the possibility of error, it is recommended that Kevlar® not be dry-cleaned. Nylon is not degraded by detergents or dry cleaning methods.

For practical purposes, Kevlar® is not affected by exposure to the environmental elements. However, under extreme conditions ultraviolet radiation can degrade the ballistic protection properties of Kevlar®. During the original

NILECJ development program, a double layer of fabric of Kevlar® 29 was left outdoors for a duration of 3 months, with one side only exposed to sunlight. Under these conditions, the ballistic properties of the outside layer are badly degraded while the second layer retains its ballistic protection properties. This data suggests that, as a further precaution, one should avoid repeated drying of armor of Kevlar® on an outdoor clothes line.

Hard body armor incorporating ceramic material must be handled carefully because it is fragile, and should be inspected immediately before actual use to insure that no surface cracks exist.

Some manufacturers market soft body armor with fabric of Kevlar® that is not treated with a water–repellent finish. In most of these instances, the design of the armor is such that the Kevlar® is sealed within a moisture barrier, such as thin plastic or coated cloth or vinyl. The owner of such armor must routinely inspect it to be sure that the cover of the ballistic inserts has not been cut or damaged, thereby allowing moisture to penetrate into the Kevlar®. Even if the outer covers have not been cut or otherwise damaged, it is still possible for the moisture barrier to be damaged. When plastic rubs over Kevlar® as a consequence of the normal flexing of the body armor in use, it can wear through the barrier and expose the armor to moisture penetration. It should also be noted that the plastic overlay tends to make the armor much warmer to wear, for it significantly reduces the rate at which perspiration can evaporate or be absorbed.

If an officer is shot or attacked with a knife while wearing body armor, be sure that a competent doctor examines him (or her) for any possible blunt trauma injury. Then, retire the armor to the trophy case and be grateful for the protection that it afforded. Undoubtedly, an officer once protected by body armor will not have to be encouraged to replace the trophy with a new set and to wear it routinely in the future.

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